NON-PUBLIC?: N
ACCESSION #: 9112120117
LICENSEE EVENT REPORT (LER)

FACILITY NAME: Salem Generating Station - Unit 2 PAGE: 1 OF 12

DOCKET NUMBER: 05000311

TITLE: Reactor/Turbine Trip on Low Auto Stop Oil Pressure Followed By Turbine/Gen. Failure
EVENT DATE: 11/09/91 LER #: 91-017-00 REPORT DATE: 12/09/91

OTHER FACILITIES INVOLVED: Salem Unit 1 DOCKET NO: 05000272

OPERATING MODE: 1 POWER LEVEL: 100

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR SECTION:
50.73(a)(2)(iv)

LICENSEE CONTACT FOR THIS LER:
NAME: M. J. Pollack - LER Coordinator TELEPHONE: (609) 339-2022

COMPONENT FAILURE DESCRIPTION:
CAUSE: B SYSTEM: TG COMPONENT: PSV MANUFACTURER: P070
REPORTABLE NPRDS:

SUPPLEMENTAL REPORT EXPECTED: No

ABSTRACT:

On 11/9/91, a Reactor Trip event occurred during performance of the monthly Auto Stop Oil System protection device testing. After the generator breaker opened (per design), a turbine overspeed condition developed resulting in failure of the turbine/generator. The reactor trip initiated while the Auto Stop Oil (AST) System test/normal lever was still in the "test" position. Following the initial drop in AST System header pressure, pressure returned. Once the AST bistable reset setpoint was reached, the turbine relatched allowing the turbine valves to reopen. Within 15 seconds of the generator output breakers' opening, the main stop valves fluctuated at the 90% open limit. Within the following 6 seconds the 4 main stop valves had gone full open. The governor valves then opened due to failure of the 63-3 AST turbine protection pressure switch to lock in the turbine trip signal in conjunction with the failure of 3 overspeed protection EHC solenoid valves (20/ET, 20-1/OPC and 20-2/OPC) to open. The operators at the front standard heard several

highly unusual sounds from the turbine and manually tripped the turbine causing closure of the turbine valves. The trip cause was blockage of the AST pressure reduction orifice. Investigation to identify the source of the foreign material is continuing. Several causal factors of the turbine failure have been identified (see main report). Corrective actions have been taken or are in the process of implementation to address these causal factors.

END OF ABSTRACT

PLANT AND SYSTEM IDENTIFICATION:

Westinghouse - Pressurized Water Reactor

Energy Industry Identification System (EIIS) codes are identified in the text as {xx}

IDENTIFICATION OF OCCURRENCE:

Reactor/Turbine Trip on Low Auto Stop Oil Pressure followed by Turbine/Generator Failure

Event Date: 11/9/91

Report Date: 12/9/91

This report was initiated by Incident Report No. 91-823.

CONDITIONS PRIOR TO OCCURRENCE:

Mode 1 Reactor Power 100% - Unit Load 1150 MWe

DESCRIPTION OF OCCURRENCE:

On November 9, 1991 at 1121 hours, a Reactor/Turbine Trip event occurred. Approximately twenty-seven (27) seconds following the trip, when the generator breaker opened (per design), a turbine overspeed condition developed resulting in failure of the turbine/generator.

At the time of the reactor trip, operations personnel were performing the monthly Auto Stop Oil System {TG} protection device testing in accordance with Operations procedure OI III-1.3.7, "Turbine Automatic Trip Mechanisms Operational Tests" (reference

attached diagram). This procedure tests the four (4) mechanical turbine protection functions which include Overspeed Trip, Vacuum Trip, Low Bearing Oil Pressure Trip and Thrust Bearing Trip.

The reactor trip initiated while the Auto Stop Oil (AST) System test/normal lever was still in the "test" position. This lever is held in the test position during each of the four (4) protective function tests. The last of the four (4) tests was in progress when the reactor trip occurred.

As identified on the Sequence of Events (SOE) recorder printout, the following was recorded within 167 milliseconds: 1. Reactor Trip; 2. 20/ET (backup turbine trip solenoid valve) energized; 3. 20/AST (electrical turbine trip solenoid valve) energized; and 4. all four (4) Main Steam System SBI stop valves indicated closed (i.e., less than 90% of their full open limit).

Within 1.5 seconds, after the initial drop in the AST System header pressure, the AST System pressure recovered. Once the AST bistable reset setpoint of 68 psig was reached, the turbine hydraulically

DESCRIPTION OF OCCURRENCE: (cont'd)

relatched, through the AST/EHC interface valve, allowing the twenty (20) turbine valves (main stop, governor, interface and reheat stop valves) to reopen.

Approximately twenty-seven (27) seconds after the initial trip signal, the main generator output breakers opened per design. This removed the load from the Turbine/Generator train.

Within 15 seconds of the generator output breakers' opening, the main stop valves fluctuated at the 90% open limit. Four (4) seconds later three (3) of the four (4) main stop valves had gone full open (i.e., greater than the 90% open limit). Two (2) seconds later the fourth main stop valve also went full open.

The governor valves then opened due to failure of the 63-3/AST turbine protection pressure switch to lock in the turbine trip signal (for the 1.5 seconds duration as seen by the 3 reactor protection pressure switches) in conjunction with the failure of three (3) overspeed protection EHC solenoid valves (20/ET, 20-1/OPC and 20-2/OPC) to open on receip
of an energization signal. In

addition, the 20/AST solenoid and the mechanical overspeed protection device were bypassed in support of the monthly front standard testing (i.e., the test lever held in the test position). This resulted in the overspeed event.

The operators at the front standard heard several highly unusual sounds from the turbine and manually tripped the turbine. This action was successful in closing the twenty (20) turbine valves.

Initial observations included: 1) Control room operators noting that the turbine analog speed meter on the EH control panel indicating a maximum scale reading of 2500 RPM, and 2) missile projectiles penetrating the turbine outer shroud (as observed by a Nuclear Equipment Operator).

Within approximately 60 seconds of the initiating event, a fire ignited at the generator. A mechanical seal failed in the Hydrogen Gas System (used to cool the generator) due to excessive vibration from the turbine overspeed. The automatic fire suppression system actuated per design. With support from Site Protection personnel, the fire was contained and extinguished within approximately fifteen (15) minutes. One individual was affected by smoke inhalation but recovered without requiring hospitalization.

All required notifications were made in accordance with Code of Federal Regulations 10CFR 50.72 and the Salem Emergency Plan. At 1140 hours the plant declared an Unusual Event based on a fire lasting greater than 10 minutes. The event was administratively upgraded to an Alert at 1244 hours due to turbine casing impingement but then was shortly downgraded to an Unusual Event based on the absence of damage to the Containment structure. The Unusual Event was terminated at 1441 hours that day.

OVERVIEW OF TURBINE DAMAGE

Various exhaust stage blading at the 22 LP Turbine governor end had severed from the rotating element and penetrated the exhaust hood. The exhaust flow guide at this location had failed and was found resting on the exhaust flow diffuser. Damage was also caused by blades impacting the condenser wall and Circulating Water tubing in two condenser hotwells.

The Turbine and Exciter ends of the main generator were involved in a hydrogen and lube oil fire. The oil return piping at both ends of

the Alterex (i.e., Exciter) was found severed. Lube oil also ignited between the low pressure turbine elements at the outboard bearing pedestal oil seals.

The turbine end generator field retaining ring had separated from its centering ring allowing it to impact the stator end windings.

Only one exhaust stage blade had severed from the generator end of the 21 LP Turbine.

Thrust bearing damage indicated that the turbine generator train had moved .065 inch toward the governor.

All remaining exhaust stage blading rows had visible blade tip damage from contact with the remaining exhaust flow guides.

After functional testing, intrusive component disassembly resulted in the following observations:

The pilot valve within the emergency trip EHC solenoid valve (20/ET) was found mechanically bound due to a small amount of accumulated debris in the pilot valve spool and rust at the DC coil side of the spool pin.

One overspeed protection EH solenoid valve (20-2/OPC) was found mechanically bound due to O-ring material lodged in the pilot valve spool.

The second overspeed protection EH solenoid valve (20-1/OPC) was found mechanically bound due to debris accumulated in the pilot valve spool.

The AST system header supply orifice was found to contain metallic debris in the form of chips, partially plugging the inlet side of the orifice assembly and also had a 3/32 inch diameter chip adhering to the surface of the inlet side of the orifice assembly.

APPARENT CAUSE OF OCCURRENCE - TURBINE TRIP:

The cause of the reactor/turbine trip event is attributed to equipment failure. Investigation has shown that the AST system oil pressure had

APPARENT CAUSE OF OCCURRENCE - TURBINE TRIP: (cont'd)

apparently decreased to below the trip setpoint for approximately 1.5 seconds and then returned to operating pressure. This pressure drop was apparently caused by the primary supply pressure reducing orifice becoming clogged. This is similar to the cause of a Unit 1 1988 reactor/turbine trip event (reference LER 272/88-015-00)

The Unit 1 event involved blockage of the orifice. However, the Unit 1 blockage was sludge (water/oil mix). Sludge was not found on the Unit 2 orifice (this LER event).

Inspection has discovered foreign material on the inlet side of the orifice. This material is being analyzed for identification. Most of the material found was in the form of flakes. The largest piece was approximately 3/32" in diameter.

The AST System was cleaned during the 1990 refueling outage per a preventive maintenance requirement created as a result of the 1988 Unit 1 event.

Other possible causes of this event included other equipment failures and a design concern with the front standard test equipment.

The suspect equipment was inspected and determined to be fully functional.

A positive indication whether the trip bypass lever was in the normal or the test position does not exist. In addition, no "detent" feature for the test lever exists while it is held in the test position. The operator, holding the trip bypass lever, may have moved it unintentionally and then moved it back within 1.5 seconds. This could have occurred by the operator flexing his hand slightly. The operator had been holding the handle for approximately twenty (20) minutes when the trip occurred. The amount of deflection of the lever would not have needed to exceed approximately one (1) inch as shown by post event testing (total travel is two (2) inches).

The unintentional movement of the trip bypass lever theory is not considered to be the cause of this event. The collected evidence indicates that the most likely cause was the orifice blockage.

A human factors study of the front standard test was conducted. Several human factors were identified which make this "routine"

monthly test "risky" for initiating a trip signal.

A review to assess the element of risk associated with front standard testing is in progress. Until completion of this assessment Salem Unit 1 monthly front standard testing will not be performed.

APPARENT CAUSE OF OCCURRENCE - TURBINE/GENERATOR FAILURE:

Following the Reactor Trip, a Turbine/Generator failure occurred. This event initiated with the failure of the 63-3 AST turbine

APPARENT CAUSE OF OCCURRENCE - TURBINE/GENERATOR FAILURE: (cont'd)

protection pressure switch to lock in the turbine trip signal (for the 1.5 second duration as sensed by the 3 reactor protection pressure switches) in conjunction with the failure of three (3) overspeed protection EHC solenoid valves (20/ET, 20-1/OPC and 20-2/OPC) to open on receipt of an energization signal. In addition, the 20/AST solenoid and the mechanical overspeed protection device were bypassed in support of the monthly front standard testing (i.e., the test lever held in the test position per procedure III-1.3.7).

Investigation to date indicates that the solenoid valve failures were not detected prior to this event due to several contributing factors which include:

1. Preventive Maintenance (PM) - The vendor does not recommend or require PM of the solenoid valves. Also, our Westinghouse Instruction manuals do not provide internal details or additional information regarding the solenoid valves.

Historically, PM was based on vendor manual direction. More recently, a Reliability Centered Maintenance (RCM) program has been initiated. The Electro-Hydraulic Control System, AST System, ... etc. have not undergone this RCM process; although they are scheduled to be done.

As indicated previously, solenoid valve PM had been initiated per LER 272/90-030-00. This PM requirement was to be implemented after replacement of the solenoid valves

also committed to by the 1990 LER.

2. Operating experience review by the industry - Three (3) industry events were not recognized or addressed as a generic industry concern; specifically, a 1985 Ginna event (reference LER 244/85-006-00), a 1990 Ginna event (reference LER 244/90-012-00), and a 1988 Crystal River event (reference LER 301/88-006-02)

These events involved turbine trip protective equipment (e.g., 20/ET failures) not functioning as designed resulting in Turbines not tripping when called on to do so. To date, the industry focus has apparently been on the primary side response and protection associated with Unit events.

3. Administrative Controls - Failure to implement commitments due to inadequate administrative controls. An administrative procedure is being prepared to detail progr
mmatic controls for implementation of commitment actions.

In September 1990, Salem Unit 1 (reference LER 272/90-030-00) a Turbine Trip/Reactor Trip event occurred.

APPARENT CAUSE OF OCCURRENCE - TURBINE/GENERATOR FAILURE: (cont'd)

Investigation of that event identified that the Unit 1 20-1/OPC and 20-2/OPC solenoid valves had functioned erratically. The LER corrective actions included replacement of the Salem Unit 2 solenoid valves "during the next outage of sufficient duration" and implementation of preventive maintenance for solenoid valves.

In May 1991, Salem Unit 2 was taken off-line in support of a planned two (2) week maintenance mini-outage. The commitment to replace the solenoid valves (per the prior Unit 1 LER) was identified on the "Forced Outage List". However, the decision was made to defer the valve replacement to the upcoming refueling outage (2R6).

4. Testing Issues

a. Failure to adequately address an apparent test failure for turbine overspeed protection performed during the October 20, 1991 startup.

This test is performed per procedure OP III-1.3.1, "Operations Department Turbine Generator Operation", during a plant startup. When the test was performed on October 20, 1991 and the test failure recognized, Control Room personnel decided to continue the startup without further probing or inquiry into the alleged "procedural problems" which may have contributed to the test failure. Operations personnel did not document this testing discrepancy nor was an Incident Report originally initiated. Subsequent to this event an Incident Report has been issued.

b. The 20-1/OPC and 20-2/OPC solenoid valves are not independently hydraulically tested with the turbine latched. Overspeed protection testing, as per OP III-1.3.1, results in joint testing of the 20-1/OPC and 20-2/OPC solenoid valves. Consequently, failure of either the 20-1/OPC or the 20-2/OPC would not be detected unless both were to fail.

Similarly, Surveillance Procedure SP (0) 4.3.2.1.3, tests the trip functions of the 20/ET and 20/AST solenoid valves together. Consequently, success of this test also fails to ensure that each of the solenoid valves are operable.

c. Technical Specification surveillance requirements on overspeed protection are not clear; i.e.,

Technical Specification 3/4.3.1 does not identify the overspeed protection systems that are required to satisfy the LCO. It refers to "at least one".

APPARENT CAUSE OF OCCURRENCE: TURBINE/GENERATOR FAILURE: (cont'd)

Independent testing of overspeed protection

devices is not required by Technical Specification 3/4.3.1

Technical Specification 3.3.4 states: "At least one turbine overspeed protection system shall be OPERABLE"

Additional factors which contributed to the cause of the turbine/generator failure include:

1. There are four (4) EHC pressure switches that enter into this event scenario. They are the three (3) reactor protection pressure switches (AST/1, AST/2 and AST/3) which provide a reactor trip signal when the AST System hydraulic fluid pressure drops below their setpoint (approximately 54 Psig). The fourth pressure switch, the 63-3 turbine protection pressure switch, signals the Westinghouse EH controller when it senses fluid pressure dropping below its setpoint of 39 psig (as found). This signal to the controller initiates ATL (automatic stop latch), tripping the turbine and preventing the turbine governor valve from reopening.

The reactor protection pressure switches are set to between 50 and 55 psig to comply with the Technical Specification requirement of "greater than 45 psig". Although not specified by Technical Specification, the 63-3 turbine protection pressure switch is set at 45 psig per the instrument schematic. The 15 psig delta (39 psig vs. 54 psig) is significant for this event. With the 63-3 AST pressure switch set low, the analog electro-hydraulic controls (AEH) did not detect the initial turbine trip condition for a time sufficient to reduce the governor valve demand to zero. This allowed the governor valves to reopen once AST System pressure was re-established and close the AST/EHC interface valve permitting high pressure trip fluid to return to normal operating pressure.

No preventive maintenance work orders exist for calibration or functional testing of the 63-3 switch. The "as-left" setting for this switch could not be determined.

2. The design of the front standard does not include positive indication of a turbine protection actuation (i.e., turbine trip).

Had the operators at the front standard been aware of the turbine trip signal when it first occurred, they possibly would have released the test lever (held during testing of the mechanical overspeed protection functions). This action would have caused completion of the Turbine Trip (via the

APPARENT CAUSE OF OCCURRENCE: TURBINE/GENERATOR FAILURE: (cont'd)

AST solenoid or the mechanical overspeed) preventing the subsequent turbine/generator failure.

3. The front standard turbine tachometer was inoperable during the performance of the front standard testing.

Had the tachometer been operable, the operator(s) at the front standard may have observed the turbine overspeed condition prior to it failing. However, it should be noted that the tachometer was not readily visible from the test location.

ANALYSIS OF OCCURRENCE:

The source of oil for the Auto Stop Oil System is the Main Turbine Lube Oil System. The "Low Auto Stop Oil Pressure" reactor trip is an anticipatory trip to a turbine/reactor trip when power is above 50% of rated thermal power (permissive P-9). This trip is intended to provide turbine protection by reducing the severity of an ensuing transient. No credit is taken in the accident analyses for the operation of this trip. Investigation revealed that the trip setpoint was approximately 54 psig, as required.

The OPC is designed to protect the turbine from overspeeding during conditions when the plant is not synchronized to the grid. The OPC is part of the EHC System {TG}. When an overspeed condition is sensed, the auxiliary governor emergency trip solenoids are designed to close the control valves and the intercept valves for ten (10) seconds and five (5) seconds, respectively. The OPC also provides an electronic close bias signal to decrease the turbine governor valve demand to zero volts, stopping steam flow in approximately 5 to 10 seconds.

Investigation found that the OPC auxiliary governor emergency trip

solenoid valves would not function (i.e., close the turbine governor and intercept valves). Also, the OPC did function to send a bias zero demand signal to the governor valves.

As stated previously, the reactor protection system functioned as designed. No damage was done to the Containment, piping to the Containment or any safety-related equipment. The emergency plan was appropriately entered and mitigating actions to handle the events following the turbine failure were appropriate and timely. Therefore, this occurrence involved no undue risk to the health and safety of the public. Because of the automatic actuation of the reactor protection system, the event is reportable in accordance with the Code of Federal Regulations 10CFR 50.73 (a) (2) (iv).

CORRECTIVE ACTION:

1. Preventive Maintenance

The foreign material found at the AST System inlet pressure

CORRECTIVE ACTION: (cont'd)

reduction orifice will be analyzed. Engineering will review results and determine additional appropriate actions (i.e., design modifications, preventive maintenance improvements, etc.).

PM for routine inspection, calibration and functional testing will be required for the EHC pressure protection switches.

A detailed root cause assessment of the 20/ET, 20-1/OPC, and 20-2/OPC solenoid failures will be completed. Design and preventive maintenance requirements will be assessed based on the results of the root cause assessment.

The prioritization of presently planned Reliability Centered Maintenance reviews will be re-assessed for systems associated with the events addressed by this LER.

2. Operating Experience

Update INPO by summerizing the circumstances of this event, the

generic issues, and implications.

This event will be reviewed with all appropriate Nuclear Department personnel.

3. Administrative Controls

Procedure revisions will be completed to independently test the four (4) turbine protection solenoid valves for full functional hydraulic operation.

Procedure NC.NA-AP.ZZ-0030, "Commitment Management" is in draft review. It will be reviewed and modified (as applicable) to ensure that responsibilities for meeting commitments are clear.

The Front Standard Turbine Test procedure (III-1.3.7) will be upgraded to the current Procedure upgrade Project standards. The Human Factors Report recommendations will be considered for input to the revision.

Technical Specification 3/4.3.4 "Turbine Overspeed Protection" will be reviewed and a License Change Request submitted to clarify the applicability of the Specification and its Surveillance requirements.

4. Testing

The need for adding instrumentation to the turbine front standard, to provide positive Turbine Trip demand indication, will be assessed.

Engineering will assess the feasibility for separating the five (5) front standard protections into individual test functions.

CORRECTIVE ACTION: (cont'd)

Engineering will review the requirements to perform vendor specified front standard testing at the 30 day frequency. Test requirements will be modified as appropriate.

A review to assess the element of risk associated with front standard testing is in progress. Until completion of this assessment Salem Unit 1 monthly front standard testing will not be performed.

A matrix review of the turbine protective functions for adequacy and completeness will be performed. It will ensure all are functionally tested with the appropriate recurring tasks in place (both Units).

5. Other

Appropriate corrective disciplinary actions have been taken with the shift personnel involved in the October 20, 1991 event for failure to take corrective action for the testing failure of OI III-1.3.1.

Engineering will review the front standard design in accordance with the Human Factors Report recommendations. Changes will be implemented as appropriate.

Engineering will review the setpoint design requirements for the EHC pressure protection switches.

The damage caused by this event will be repaired and appropriate testing will be performed prior to returning the Unit to service.

The front standard tachometer will be repaired.

General Manager -
Salem Operations

MJP:pc

SORC Mtg. 91-123

Figure "Electro-Hydraulic Fluid System, Auto-Stop Oil System" omitted.

PSE&G
Public Service Electric and Gas Company
P.O. Box 236 Hancocks Bridge, New Jersey 08038

Salem Generating Station

December 9, 1991

U. S. Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555

Dear Sir:

SALEM GENERATING STATION
LICENSE NO. DPR-75
DOCKET NO. 50-311
UNIT NO. 2

LICENSEE EVENT REPORT 91-017-00

This Licensee Event Report is being submitted pursuant to the requirements of the Code of Federal Regulations 10CFR 50.73 (a) (2) (i) (B). This report is required within thirty (30) days of discovery.

Sincerely yours,

C. A. Vondra
General Manager -
Salem Operations

MJP:pc

Distribution

*** END OF DOCUMENT ***